New York State Water Resources Institute
Annual Technical Report
FY 2016

Introduction

The Mission of the New York State Water Resources Institute (WRI) is to improve the management of water resources in New York State and the nation. As a federally and state mandated institution located at Cornell University, WRI is uniquely situated to access scientific and technical resources that are relevant to New York State's and the nation's water management needs. WRI collaborates with regional, state, and national partners to increase awareness of emerging water resources issues and to develop and assess new water management technologies and policies. WRI connects the water research and water management communities. Collaboration with New York partners is undertaken in order to: 1) Build and maintain a broad, active network of water resources researchers and managers, 2) Bring together water researchers and water resources managers to address critical water resource problems, and 3) Identify, adopt, develop and make available resources to improve information transfer on water resources management and technologies to educators, managers, policy makers, and the public.

Research Program Introduction

The NYS WRI's FY2016 competitive grants research program was conducted in partnership with the NYS Department of Environmental Conservation (DEC) Hudson River Estuary Program (HREP). The overall objective of this program is to bring innovative science to watershed planning, management and policy. In FY2016 research was sought that fit within the context of New York State's concerns about aging public water resources infrastructure and related economic constraints on public investment. Additionally, competitive funding was directed toward projects that incorporated analysis of climate change and/or extreme weather and their impacts on communities, ecosystems, and infrastructure. The specific areas of interest for the FY2016 grants program solicitation were: 1) The current state and effectiveness of water-related infrastructure including water supply and wastewater treatment facilities; natural and "green" infrastructure; decentralized treatment installations; dams; culverts and bridges; constructed wetlands; etc., at providing water services regionally at reasonable cost; and understanding the connections between watershed protection, drinking water management, and aquatic life needs; 2) Effects of climate change and extreme weather impacts on New York's communities, and assessment of the resilience of ecosystems, infrastructure, communities, and governance institutions to climate change and/or development of strategies to increase such resiliency; 3) Integration of scientific, economic, planning/governmental and/or social expertise to build comprehensive strategies for local public asset and watershed managers and stakeholders; 4) Novel outreach methods that enhance the communication and impact of science-based innovation to water resource managers, policy makers, and the public; and 5) The relationship between management in the Hudson River watershed and the estuary ecosystem's fish and wildlife, and water quality and quantity.

Projects were evaluated by a panel consisting of 5 WRI staff representatives, 1 Cornell University faculty member, 1 staff member from the NYS Department of Environmental Conservation, and 2 representatives from other NY-based academic institutions. Four research projects were initiated with 104b base funding, while another five were initiated and funded through DEC sources that WRI leverages with its base federal grant. For FY2015, 104b-funded projects include:

1. Water Quality and Algal Community Dynamics in the Finger Lakes PI: Lisa Cleckner, Hobart & William Smith College

2. Evaluating Septic System Inputs into Sodus Bay using Oblique Imagery, Optical Brighteners, and DNA-based tracers PI: Paul Richards, SUNY-Brockport

3. Student Researcher Support of Adaptive Management of the St Lawrence River using Novel Water Quality Monitoring Methodology PI: Michael Twiss, Clarkson University

4. Innovative water treatment by chitosan modified diatomaceous earth for small public water systems in rural areas PI: Steven Wei, SUNY-Polytechnic Institute

Additionally, WRI staff funded in part by the 104b program engaged in ad hoc research activities, the results of which are reported on below (authors in **bold** indicate WRI researchers):

Trulhar, A.M.; **Rahm, B.G.**; Brooks, R.A.; Nadeau, S.A.; Makarsky, E.T.; **Walter, M.T.** "Greenhouse gas emissions from septic systems in New York State" J. Environ. Qual. 2016, 55 (4), 1153-1160

Rahm, B.G.; Hill, N.B.; Shaw, S.B.; **Riha, S.J.** "Nitrate dynamics in two streams impacted by wastewater treatment plant discharge: point sources or sinks?" J. Am. Water Resour. As. 2016, 52 (3), 592-604

Water Quality and Algal Community Dynamics in the Finger Lakes

Basic Information

Title:	Water Quality and Algal Community Dynamics in the Finger Lakes
Project Number:	2016NY226B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	NY-23
Research Category:	Water Quality
Focus Category:	Water Quality, Water Supply, Nutrients
Descriptors:	None
Principal Investigators:	Lisa B Cleckner, Roxanne Razavi, John Halfman

Publications

There are no publications.

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Water quality and algal community dynamics in the Finger Lakes

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Abstract

Nutrient loading has resulted in the proliferation of harmful algal blooms (HABs) in freshwaters worldwide. Most HABs are composed of cyanobacteria, also known as blue-green algae, which can harm human and animal health when they produce cyanotoxins. Ubiquitous HABs represent a serious problem across waterbodies in New York State and the Finger Lakes. Studies of algal community dynamics can help illuminate factors that lead to increases in HABs. Advanced sensor technology allows for *in situ* measurements of chlorophyll differentiated by algal class. In this study, a FluoroProbe spectrofluorometer (bbe moldaenke, GmbH) was used to assess four major phytoplankton groups in the pelagic and nearshore of two Finger Lakes (i.e., Honeoye and Canandaigua Lakes). The objective of this work was to determine whether pelagic sampling reflects nearshore algal communities, and how this varies by lake trophic status. Seasonal changes in algal communities were also assessed, and water quality parameters that best explain phytoplankton succession and specifically cyanobacteria are evaluated.

Three Summary Points of Interest

- **Nearshore algal communities mostly reflected offshore sites with the exception of two nearshore outlier sites**
- **Temporal trends in algal communities were evident with increases in organisms containing phycoerythrin and phycocyanin (cryptophytes and cyanobacteria) observed in both oligotrophic and eutrophic lakes**
- **Bioavailable forms of phosphorus and nitrogen were not strongly correlated with concentrations of total chlorophyll-a and cyanobacteria**

Keywords

Harmful algal blooms, phytoplankton, water quality, sensor, lake

Introduction

Water quality and supply is dependent on both the abiotic conditions in a system and the biotic communities they support. Maintenance of water quality and sustainable water supplies require continued research given changes in population sizes and land use, energy development, nutrient and contaminant inputs, and climate patterns. A major trend of concern in freshwaters is the increase in cyanobacteria, also known as blue-green algae, that are responsible for harmful algal blooms (HABs). In NYS, HABs have become a critical issue affecting drinking and recreational waters. The Finger Lakes of Central and Western New York include three of the largest lakes in the state and represent a drinking water source for over a million NYS residents. In 2015, over half of the Finger Lakes experienced HABs, and the toxin microcystin produced by the genus *Microcystis* was detected in several lakes including Honeoye, Canandaigua, and Owasco Lakes. In 2016, the year of this study, this trend continued, and alarmingly, microcystin was detected in finished drinking water in Owasco Lake (NYSDEC 2017).

Assessing water quality to predict HABs is an important step in understanding factors that lead to their proliferation. The supply of nutrients and light primarily controls phytoplankton succession (Sommer et al. 2012). Phosphorus (P) has been shown to influence the abundance of cyanobacteria (Schindler et al. 2008), and the importance of nitrogen (N) is also increasingly recognized as an important control on their growth (Glibert et al. 2016, McCarthy et al. 2016). In addition to nutrient supply, cyanobacteria should be assessed within the context of the algal community, in part because various algal groups prefer specific nutrient sources (e.g., cyanobacteria are more competitive for ammonium and diatoms are more competitive for nitrate, Glibert and Berg 2009).

The purpose of this study was to characterize water quality and algal communities in a representative oligotrophic and eutrophic lake in the Finger Lakes, NY (**Figure 1**). Advanced sensor technology was used for *in situ* measurements of chlorophyll differentiated by algal class. Specifically, the FluoroProbe spectrofluorometer (bbe moldaenke, GmbH) was purchased and employed to differentiate four major phytoplankton groups (green algae, diatoms/dinoflagellates, cryptophytes, and cyanobacteria). The objectives of the study were to determine i) whether offshore sampling sites, often sampled to represent lake water quality in monitoring programs, reflect water quality and algal communities at the nearshore, where recreational use dominates, ii) whether temporal trends in algal community dynamics are more important than spatial differences within a lake, and iii) whether water quality, specifically the bioavailable forms of P (soluble reactive phosphorus, SRP) and N (ammonium, NH_4) are strong predictors of total chlorophyll-a and specifically cyanobacteria concentrations in the Finger Lakes.

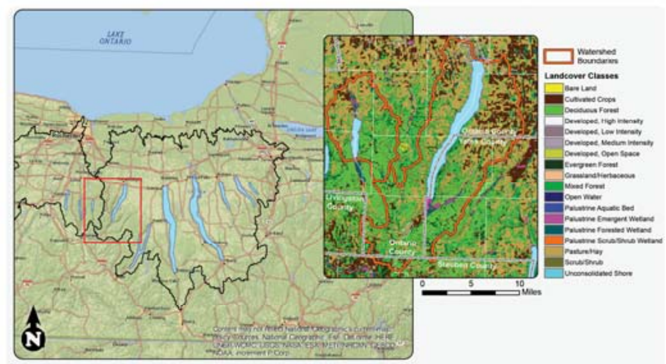

Figure 1. The Finger Lakes of Central and Western New York. Honeoye Lake (inset left) and Canandaigua Lake (inset right) were the focus of this study.

Results & Discussion

Result 1: Similarities between nearshore and offshore phytoplankton composition vary by lake and algal group

In Canandaigua Lake, we found no difference between nearshore and offshore (in the top 10 m) concentrations for all the algal groups except one. Cyanobacteria at a single nearshore site (Fall Brook; FB) was significantly different than all other nearshore and offshore sites within Canandaigua Lake (ANOVA, F ratio = 3.36, $p = 0.0009$, $n = 84$; **Figure 2a**). In Honeoye Lake, significantly higher concentrations of cryptophytes (and/or phycoerythrin-producing cyanobacteria which can be misattributed by the FluoroProbe, Catherine et al. 2012) were observed at a single nearshore site (Joe Bear; JB) compared to the offshore site and the nearshore site at the inlet (ANOVA, F ratio=3.48, $p = 0.0174$, $n = 39$). This same nearshore site had an overall higher total chlorophyll-a compared to the offshore site and the

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nearshore site at the inlet (ANOVA, F ratio=3.82, p=0.0114, n =39; **Figure 2b**).

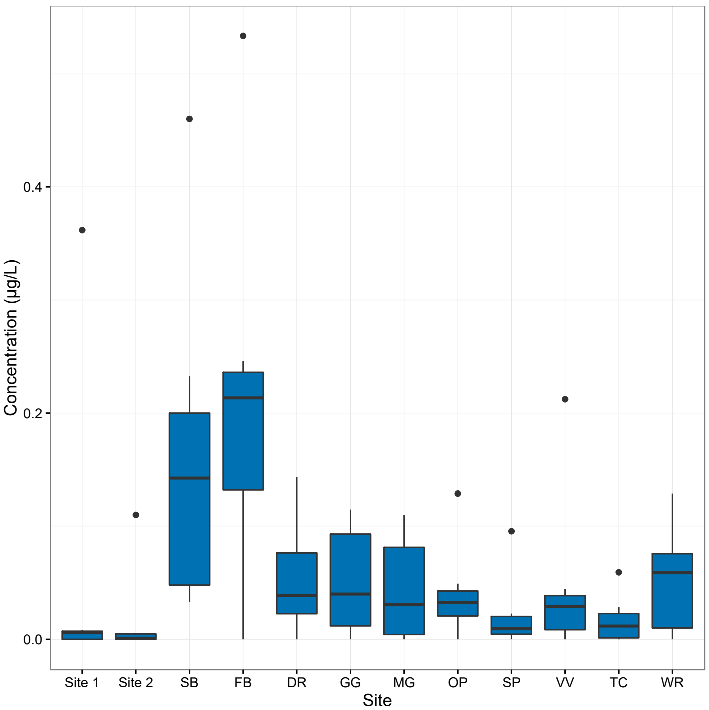

Figure 2a. Cyanobacteria concentrations were significantly higher in only one nearshore site (Fall Brook; FB) on Canandaigua Lake (Site 1 and 2 represent offshore sites). Each boxplot represents seven weeks of sampling (n = 7, each point is the mean for a given sampling date).

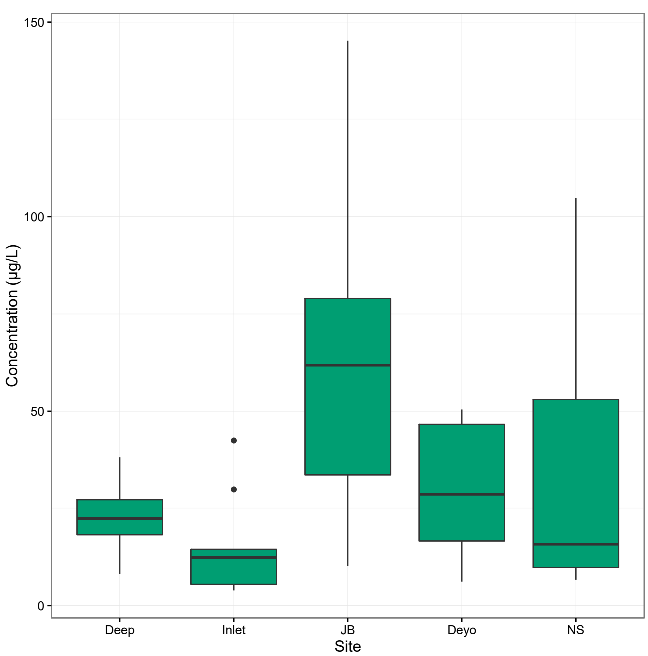

Figure 2b. Total chlorophyll-a concentrations (and phycoerythrin identified as cryptophytes, not shown) were significantly higher at one nearshore site (Joe Bear; JB) compared to the nearshore site at the inlet (Inlet) and the offshore site (Deep). Each boxplot represents weeks of sampling (n = 10, each point is the mean for a given sampling date). Note difference in scale on the y-axis compared to Figure 2a.

It appears that the offshore sampling sites were in fact representative of the algal communities at the majority of the nearshore sampling sites. However, the two nearshore outlier sites identified suggest that localized effects can occur. In the case of Fall Brook on Canandaigua Lake, this site is affected by the input of the Fall Brook tributary. This tributary is known to have among the highest phosphorus and especially nitrogen concentrations among all tributaries to the lake (Canandaigua Lake Watershed Management Plan 2014). In the case of Joe Bear on Honeoye Lake, this site is located within a cove on the lake, and as such, wind patterns often cause accumulation of phytoplankton in the cove. The FluoroProbe sampling was able to document these differences and proved to be a valuable tool for identifying localized cyanobacteria hotspots within a lake.

Result 2: Species composition varies seasonally and in a similar way between lakes of varying trophic status

In the oligotrophic lake (i.e., Canandaigua Lake), mean phycocyanin and phycoerythrin (i.e., cyanobacteria and cryptophyte) concentrations increased significantly across the sampling period for all sites combined using linear regression analysis (Cyanobacteria (µg/L) = -53 + 1.5e-8*Date, R^2=0.13 p=0.0008 n= 84; Cryptophytes (µg/L) = -343 + 9.7e-8*Date, R^2=0.50; p<0.0001, n=84). No other significant increases were observed for other algal groups. However, linear regression analysis does not capture the increase in green algae, diatoms, and total chlorophyll-a in late August, a peak that did not coincide with the phycocyanin and phycoerythrin peak in late September (**Figure 3**).

In the eutrophic lake (i.e., Honeoye Lake), temporal changes in mean concentration were evident for all sites (the analysis was run without the nearshore site (i.e., JB) that was significantly different in the spatial analysis). A significant decrease in green algae concentrations and

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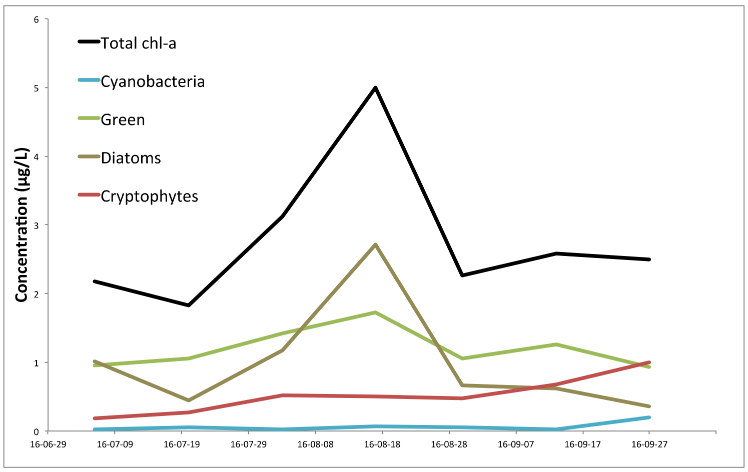
significant increase in phycoerythrin concentrations was observed using linear regression analysis (Green algae (µg/L) = 2187 - 6.1e-7*Date, R^2 = 0.12, p =0.012, n = 51; Cryptophytes (µg/L) = -3141 +8.9e-7*Date, R^2 = 0.08, p = 0.04, n =51). Increasing trends in phycocyanin and total chlorophyll-a were also seen but were not significant (**Figure 3**). Additional statistical analyses will be explored to best characterize temporal trends in phytoplankton composition as well as to characterize how those changes compare to seasonal changes in water quality.



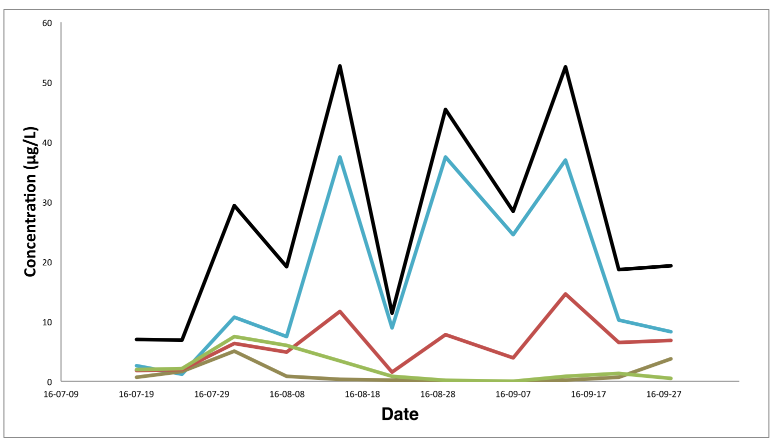


Figure 3. Mean concentrations of chlorophyll by algal group for Canandaigua Lake **(top)** and Honeoye Lake (**bottom).** Time series were constructed using means of all sites on a given date (*n* = 10 and *n* = 4 per date for Canandaigua and Honeoye Lake, respectively). Note the difference in the y-axis scale.

In both the eutrophic and oligotrophic lake, significant increases in phycoerythrin (identified as cryptophyte by the FluoroProbe) were observed between July and September 2016. Both lakes also showed increases in phycocyanin (identified as cyanobacteria by the FluoroProbe) over the sampling period although the increase was not significant in Honeoye Lake. This may result from the fact that Honeoye Lake has highly elevated concentrations of phycocyanin throughout the sampling period. Cyanobacteria have optimal growth at high temperatures (over 25°C) at which they can outcompete eukaryotic algae (Paerl et al. 2011). The peak in chlorophyll observed in Canandaigua Lake was prior to a single rain event (August 22 2016) so it is not clear if this reflects instead a release in pressure from grazing by zooplankton or some other physical control. The rain on August 22 did result in a turnover event on Honeoye Lake. Chlorophyll-a concentrations increased in the subsequent sampling (August 28 2016), but more importantly, a switch from N-fixers (i.e., *Anabaena and Gloeotrichia*) to non-N fixers (i.e., *Microcystis*) was observed. The FluoroProbe is not able to characterize these species differences within algal groups. These species differences reflect important changes in nutrient availability. Therefore, the FluoroProbe should be used in conjunction with other methods to assess the functional differences in algal species as well as taxonomic changes through time.

Result 3: SRP and NH4 were not strongly correlated with concentrations of total chlorophyll-a and cyanobacteria
The bioavailable fractions of P (i.e., SRP) and N (i.e., NH4) were not strongly correlated with concentrations of cyanobacteria regardless of lake trophic status (**Table 1**). Relatively stronger correlations between nutrients and total chlorophyll-a were found for the oligotrophic lake (Canandaigua) compared to the eutrophic lake (Honeoye). Future work will assess whether other water quality variables measured, such as total P, silica, TSS, temperature, and/or conductivity are stronger explanatory variables. These results may also reflect the severe drought conditions during the summer of 2016.

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Table 1. Results of a multivariate correlation analysis of soluble reactive phosphorus (SRP) and ammonium (NH4) on chlorophyll-a concentrations (i.e., total and phycocyanin, identified as cyanobacteria by the FluoroProbe).

	Total chlorophyll (µg/L)	Cyanobacteria (µg/L)
Canandaigua Lake (*n* = 90)		
SRP (µg/L)	0.11	-0.02
NH4 (µg/L)	-0.20	0.08
Honeoye Lake (*n* = 40)		
SRP (µg/L)	0.01	0.04
NH4 (µg/L)	-0.05	-0.01

Cyanobacteria are particularly well adapted to uptake of NH4 (Glibert et al. 2016), so a positive trend with NH4 was expected. Although there was only a weak correlation of NH4 with concentrations of phycocyanin in Canandaigua Lake, the highest concentration of NH4 was observed at Fall Brook (data not shown), which coincided with the highest concentration of phycocyanin (identified as cyanobacteria by the FluoroProbe) observed at any site on this oligotrophic lake. The lack of strong relationships between SRP and NH4 may be due to the lack of significant differences in SRP among sites observed in Canandaigua Lake, and similarly the lack of significant differences among sites in NH4 and SRP in Honeoye Lake. Future work will examine within site trends in NH4 and SRP on the other taxonomic groups and specifically the proportion of each group as previous work found proportions varied strongly with N concentrations (Glibert and Berg 2009).

Policy Implications

The FluoroProbe project was a welcome addition to the Finger Lakes region. Many watershed associations and utilities are concerned about the presence of HABs in the lakes, and the Fluoroprobe was used to screen samples as part of an inaugural citizen science program on Seneca Lake where over 30 zones were surveilled once a week from August through September 2016. Partners in this program were the NYSDEC and Seneca Lake Pure Waters Association with the FLI. If samples submitted by citizens had phycocyanin concentrations > 20 µg/L then the sample was filtered and sent to SUNY-ESF for toxin analysis. Of the ten samples submitted, two samples had high toxin levels (microcystin). Use of the FluoroProbe was also requested by the Canandaigua Lake Watershed Council to follow-up on a suspected bloom event. Many Finger Lakes citizens are aware of the health threat posed by HAB events and the FluoroProbe was deployed to provide quick confirmation of the presence of phycocyanin (i.e., cyanobacteria) in surface waters. In turn, this information was subsequently shared with county health departments, which resulted in public notices online and in many newspapers.

Methods

Between May and September 2016, ten nearshore sites and two offshore sites were sampled on Canandaigua Lake and 4 nearshore sites and one offshore site was sampled on Honeoye Lake. FluoroProbe data was collected between July and September 2016 with a loaner FluoroProbe (the FluoroProbe received in May 2016 had a hardware malfunction and was returned to Germany). Cross-contour transects at three tributaries of each lake were not possible due to the severe drought in 2016; inputs from tributaries in 2016 were deemed to be minimal.

Bi-weekly water quality and FluoroProbe measurements were made at all sites. Water samples were analyzed following standard protocols for total phosphorus, soluble reactive phosphorus, ammonium, nitrate, total suspended solids, and silicate. All water quality samples for Canandaigua Lake were run at Hobart and William Smith Colleges (John Halfman). Collaborators from Wright State University analyzed all nearshore samples for ammonium (NH_4) and all nearshore samples for Honeoye Lake for soluble reactive phosphorus (SRP). Nearshore total phosphorus samples for Honeoye Lake were analyzed at Cornell University in the Hairston laboratory.

Outreach Comments

There was an informational display about the FluoroProbe during a hands-on session at the 3rd Annual Finger Lakes Harmful Algal Blooms (HABs) seminar (August 10th 2016, Hobart and William Smith Colleges). This seminar series is a collaboration among Corning Incorporated, the NY Upstate Chapter of the U.S. Green

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Building Council, and the FLI. Attendees include representatives of municipalities, NYS Parks & Recreation, the NYSDEC, county agencies, watershed associations, and professionals. The seminar provides continuing education credit primarily for engineers and architects through the American Institute of Architects.

Student Training

An undergraduate student (Kely Amejecor, HWS '18) was hired to work with the FLI lab manager and postdoc to take FluoroProbe samples on Honeoye and Canandaigua Lakes over the summer of 2016. This student also assisted in the processing of samples from the Seneca Lake HABs monitoring program. The student used preliminary data from Canandaigua Lake for his summer research project and presented a poster "A study of nutrient and phytoplankton composition in Canandaigua Lake using a FluoroProbe" at the HWS Summer Research Conference (Saturday September 17, 2016). Kely's summer research experience at the FLI made him competitive to accept a summer research position at the University of Toledo. He intends to do an Honor's project in the fall of 2017 using data collected by the FluoroProbe.

Additional final reports related to water resource research are available at http://wri.cals.cornell.edu/news/research-reports

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Evaluating Septic System Inputs into Sodus Bay using Oblique Imagery, Optical Brighteners, and DNA-based tracers

Basic Information

Title:	Evaluating Septic System Inputs into Sodus Bay using Oblique Imagery, Optical Brighteners, and DNA-based tracers
Project Number:	2016NY227B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	NY-024
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Wastewater
Descriptors:	None
Principal Investigators:	Paul L Richards

Publications

There are no publications.

Proof of Concept: Tracing Septic Pollution Sources using DNA Nanobiotechnology

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Abstract

Septic and sewage pollution of groundwater and soil has been an issue difficult to handle. Specifying the exact location of a leak is a long, expensive process that may require replacement of entire septic systems. This paper investigates the validity of using unique DNA-based water tracers to identify leaking septic systems. This technology would be especially useful if applied to many septic systems simultaneously to determine which contributes most to pollution. The studies was conducted when the groundwater table and soil water content were high after snow melt in February, at a sites in Rush, NY (experiment 1) and Webster, NY (experiment 2). Unlike other tracer technologies, the DNA tracer can be detected at low concentrations through the use of quantitative polymerase chain reaction (qPCR) amplification technology and does not appear to be degraded by passing through septic tanks, soil columns, or streams.

Key words: Septic tank, DNA tracer, groundwater, qPCR, nanobiotechnology

Background and Motivation

Septic and sewage leaks have negative impacts on water quality and soil chemistry in near as well as distant environments. Leaks pose health hazards like norovirus and other gastrointestinal diseases associated with fecal contaminated groundwater (Borchardt, 2011). Increased nutrient loads and discharge volumes to surrounding streams can also be significant, especially in smaller headwater streams (Withers et al., 2011). The issue of increased concentrations of previously unregulated wastewater contaminants known as pharmaceutical and personal care products (PPCPs) such as human and pet over-the-counter drugs and prescription medications or cleaning/sanitizing chemicals is also a rising concern. PPCPs can pose great threat due to their continuous introduction, despite potentially rapid degradation (Ellis, 2006). Leaky small and large scale septic and sewage systems can add sulphate, chloride, nitrogen, and phosphate loads to groundwater, changing the nutrient dynamics surrounding the leak and downstream (Fishwirth & Hotzl 1997).

DiSilva et al. (2005) generated a model to determine when sewer and analogously septic lines and systems should to be replaced as a function of soil type and stability, pipe deterioration, infiltration and exfiltration from/to groundwater, and potential blockages. The DiSilva model is designed to make the most cost-effective estimate of when pipes should be replaced to avoid failures. This model acts as a great preventative measure so that systems can be replaced before leaks spring, but it does not provide a mechanism for pinpointing the location of a leak once it already exists.

Traditional tracers such as dyes, salts and ionic ratios have been used to detect leakage locations by monitoring concentration fluctuations at differing points in the system itself and the surrounding groundwater (Ellis, 2001). Ionic ratios are not optimal tracers because ionic signatures of waste sources can change between sources and degenerate with chemical reactions within the sewage system. Ionic ratios, dyes, and salts can all fail when rainwater infiltration into the system is neglected (Ellis, 2001). Detecting septic leaks has taken several paths in the last few decades. Fishwirth and Hotzel (1997) detected leaks by identifying elevated groundwater concentrations of nitrate, chloride, and phosphate. Fahrenfeld et al (2016) used fecal sterol analysis to determine presence and absence of human fecal contamination. However, none of these technologies allow for the determination of which septic tanks among multiple are contributing to water quality degradation.

There are a variety of source tracking methods for fecal bacteria and fecal indicator bacteria, each requiring extensive analysis and experimental set up to determine sources (Field, 2007). Fluorescent dyes have also been used to determine if septic systems contaminate groundwater supply (Borchardt, 2011). Although Borchardt used florescent dyes to determine the point of leakage in a *single* system, this technology could be applied to various systems leaking into the same water body. Smart & Laidlaw (1977) found that of the 8 most commonly used florescent dyes, only three were recommended for use due to photo decay by sunlight, adsorption to surfaces, background florescence values and detection limits. The three recommended tracers are more robust than the others, though they are still subject to the same limitations to a lesser degree than the other five dyes studied.

Introduction

A promising new technology, previously used for other water tracing applications, could be applied to leaking septic systems to identify the problem septic system out of many. The novel DNA tracer technique, as used by Sharma et al (2009), would provide a unique identifier to determine which system among many is the one contributing to water and soil contamination. Additionally, the low detection limit of less than 100 copies of DNA per sample (see Figure 3 for standard curve) makes this tracer ideal for systems with large dilution factors.

The DNA tracer advantage is that unlike former technologies which require testing many different stream/water body reaches to identify the location of highest fecal contamination or those using dyes/salt tracers which require thorough flushing to test a separate septic system, DNA tracers may be used to simultaneously test all septic systems in a watershed and sample at just one final drainage point.

Using this technique, a unique DNA tracer would be applied in each septic system, by flushing it down a toilet or sink. Because DNA is the unique component, theoretically hundreds of differently identifiable tracers can be made and distinguished. Samples from the contaminated water body should show tracers that traveled with septic leachate into the water system. A traditional breakthrough curve should be distinguishable if samples are taken at an appropriate time interval after quantitative polymerase chain reaction (qPCR) is preformed on the specific sequence encapsulated in the DNA tracer's protective sphere.

The qPCR method theoretically can differentiate concentrations of DNA to 0-10 strands per sample if the standard curve in Figure 2 is extended to lower concentrations. Extending the standard curve is not advised on either the high or low end as beyond the concentrations used in Figure 2 the relationship becomes non-linear. Each DNA tracer must have its own empirically derived standard curve. Different strands of DNA, and their respective forward and reverse primers, interact and inhibit the qPCR process differently. For this reason, standard curves cannot be transferred between tracers and must be run for each tracer used.

Proof of concept

Experiment 1:

The DNA tracers are uniquely identifiable single-stranded DNA encapsulated by a Polylactic Acid (PLA) sphere fabricated with the procedure used in Sharma et al (2009). PLA has been determined to be biodegradable and nontoxic in the environment made from annually renewable resources (Garlotta, 2001). Until this point the tracers had been tested in glacial melt water to determine flow paths (Dahlke et al, 2015), in stream experiments (Sharma, 2012), run through a septic test case (Richards, 2016), used as limestone bedrock groundwater tracers to trace flow paths (Aquilanti, 2016), and as oil tags (Puddu, 2014). The tracers have also been tested in a variety of unpublished experiments to determine if they can travel through a soil column, if they settle out of solution within reasonable time, and if they can be detected in streams of order and volume greater than that in Sharma et al (2009).

Experimental set up

To test the application of DNA tracers in septic systems, a single bedroom residence was chosen with a septic tank of 500 gal **(Figure 1)**. The experimental site was located in Rush, NY where the local depth to groundwater was on average 0.4m from the surface during the experiment across all 4 wells used. The septic tank is located 12.5 m away from a wetland, with the leach field 11.3 m away from the wetland. This set up was designed to determine if the tracers would be detectable in drilled wells as well as in the wetland. Seven wells were drilled (wells 0-7) and one existing well (well 8) was used to determine leachate flow path. After determining likely routes using electrical conductivity measurements (as in Alhajjar et al, 1990), 4 wells were sampled for the duration of the experiment (Wells 0-3). Wells 1, 2, and 3 are located 2 ft before the saturated area of the wetland and well 0 is in the leach field. The three wells closest to the wetland were located 7.3 and 4.4 m apart (See Figure 1 for experimental set up). Additional wells were sampled at the start of the experiment to determine base electrical conductivity and ambient false positive DNA of the groundwater samples (Wells 4-8).

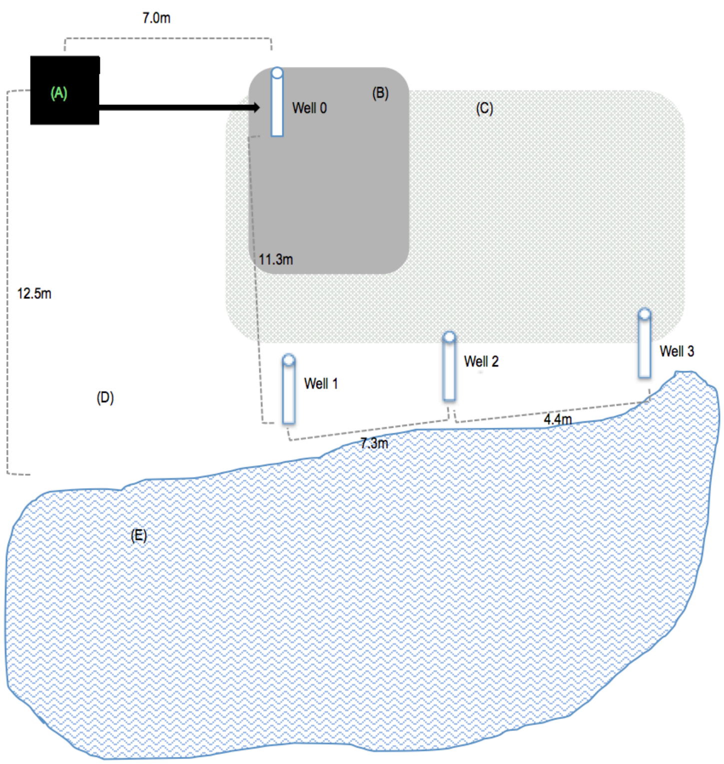


Figure 1: Experimental set up. The septic take is connected to a single bedroom residence, inhabited by one person. The labeled items in the figure are A) septic tank, B) leachfield, C) forested area, D) mowed lawn that extends above leach field and forested area, and E) wetland. Beyond the wetland is Honeoye Creek, the outlet of Honeoye Lake. In this experiment, the tracer travels through 5 to 13 meters of silt loam underlain by clay before reaching the sampling wells.

<u>Experiment 2:</u>
The second experiment was conducted in a three bedroom home in Webster, NY, located 100 meters from an unnamed tributary of Four Mile Creek (**Figure 2**). The house has a 1000 gallon septic tank. The leachfield is located in the front yard and was properly built to code and is approximately 250 meters from a small stream. No issues have been reported in the septic system in the past. An ISCO automatic stream sampler was installed in the tributary approximately 1 km downstream, below the leachfield. This experiment is thus a realistic full

scale test of the methodology, requiring the tracer to travel through 250 meters of gravel loam and down a stream one kilometer to the sampling site. The full effects of dilution from upstream and groundwater flow will have incurred before the tracer is sampled. On November 7, 2015 45mg of T3 tracer was introduced into the downstairs toilet of the residence. The stream was then sampled for the tracer over a 32 day period.

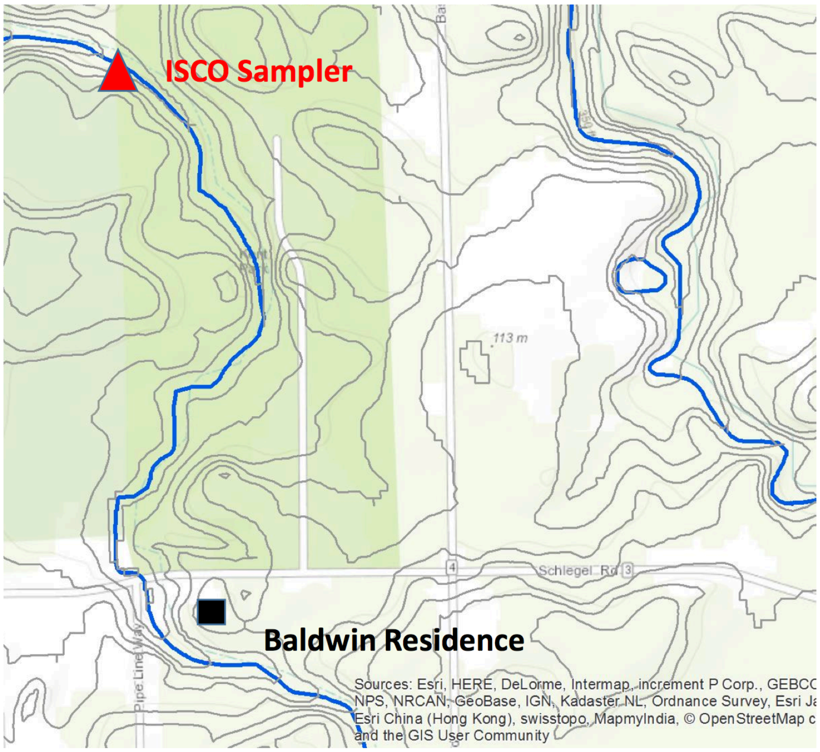


Figure 2: Experiment 2 set up. The septic take is connected to a three bedroom residence, inhabited by three people. This residence is marked by the black box icon. The tracer in this experiment will have traveled through a minimum of 250 meter of gravel loam and then along 1 kilometer of stream. Samples were collected at the red triangular icon

Methods:

Sampling protocols

During a pre-experiment 1 test at of the sampling protocol (Richards et al, 2016), it was determined that the residence time of the tracers in the septic tank was less than 24 hours, so sample intervals were set at 30 minute intervals for 12 hours, with a final sample the morning after the experiment began. A PVC ball bailer slurry sampler was used to sample wells, rinsing the sampler between wells and sample iterations. Samples were stored in 60mL Nalgene bottles and refrigerated until analysis. Wells were installed 4 months prior to running the experiment.

In experiment 2 an ISCO sampler was used to take 500ml of stream water in HDPF containers every 12 hours. The sampler was emptied every two weeks.

Analysis Procedure

In experiment 1 samples were analyzed 2 days after collection using qPCR with a BIORAD CFX96 Real-Time System, C1000 Thermal Cycler and iTaq Universal SYBR Green Supermix from BIORAD. Samples were run in a three-step protocol to match the most effective annealing temperature of the specific DNA strand tested. All samples were normalized to the base fluorescence value of groundwater for each sample run. Duplicates of all samples were run, and values averaged. Extreme differences in the duplicates were attributed to contamination and false positives and duplicates more than 50-100 copies of DNA different were compared with surrounding samples and outliers removed. The mean difference of copies between duplicates was 16.9 copies; standard deviation of the mean difference was 23.3 copies. 4.4µL of sample were tested with 5.6µL of combined BioRad SYBR Green Supermix, forward and reverse primers, and nuclease free water.

In experiment 2, samples were analyzed between 2 and 14 days after they were collected, depending on when the sample was taken relative to when the ISCO sampler was emptied. No preservation steps were taken, so the samples were subject to up to 14 days of natural outdoor temperature variation. The samples were then analyzed using qPCR as discussed in experiment 1 above.

Standard Curve

A standard curve was generated using serial dilutions from tracer stock solution before the experiment to determine the approximate detection range and relationship between qPCR machine output and total number of DNA copies.

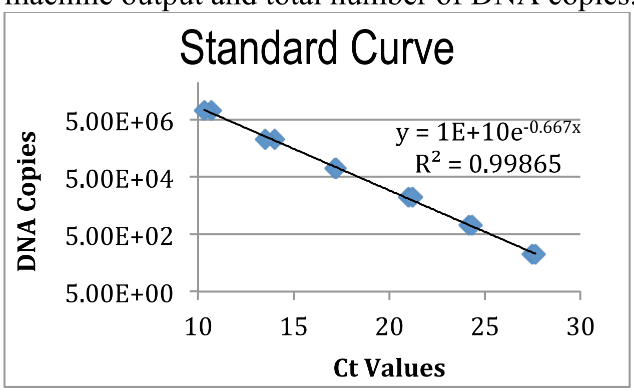


Figure 3: Standard curve relating qPCR machine output to total copies of DNA in sample. Standards should be run for each DNA strand because strands interact in different ways. The horizontal axis (Ct Values) indicates the number of cycles the qPCR machine takes to exponentially grow the DNA concentration to reach the threshold fluorescence value that can be detected by the optical sensors.

Results and Discussion:

Each of the 4 sampled wells indicates that the tracer reached the well at some point during the first 9 hours of the experiment and likely continued to be flushed out of the system after the conclusion of the experiment (**Figure 4**). Time '0:00' coincides with the flushing of the tracers down the residence toilet. The peak values are slightly shifted for each well, as would be expected for differing distances from the leachfield and potentially varied flow paths.

Well 0, located within the leachfield, showed the highest tracer concentration and displayed 3 local maxima. The first of these maxima came before any other peak in any well (at 4.5 hours).

These local maxima are believed to coincide with different volumetric water additions to the septic system.

Well 1's breakthrough curve starts at 5.5 hours, 1 hour after the first peak in Well 0. Well 1 lays downslope from Well 0, as is expected from the experimental set up (see Figure 1). Well 2 indicates the start of the breakthrough curve starting around 4.0 hours and peaking at 5.0 hrs. Because this peak comes so soon after first seeing the tracer in the leachfield at Well 0, it is possible that the leachfield is short circuiting to Well 2.

Well 3 has a breakthrough curve starting at 5.0 hours and peaking at 8.5 hours. This later peak is expected for Well 3 as it is farthest from the leachfield.

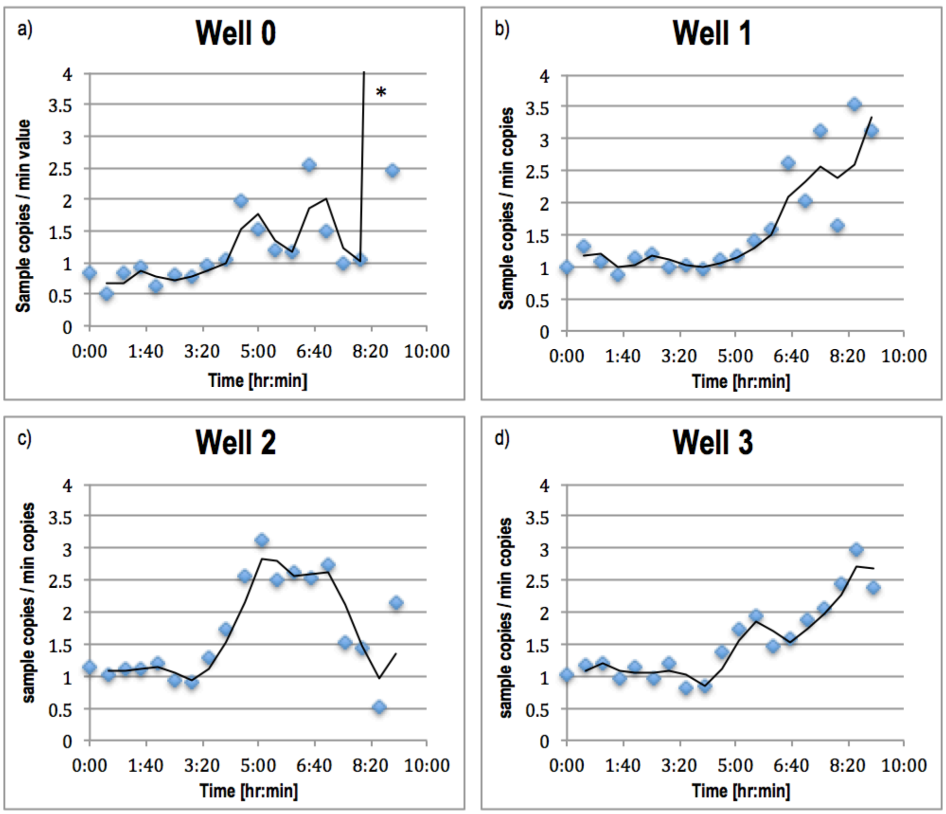
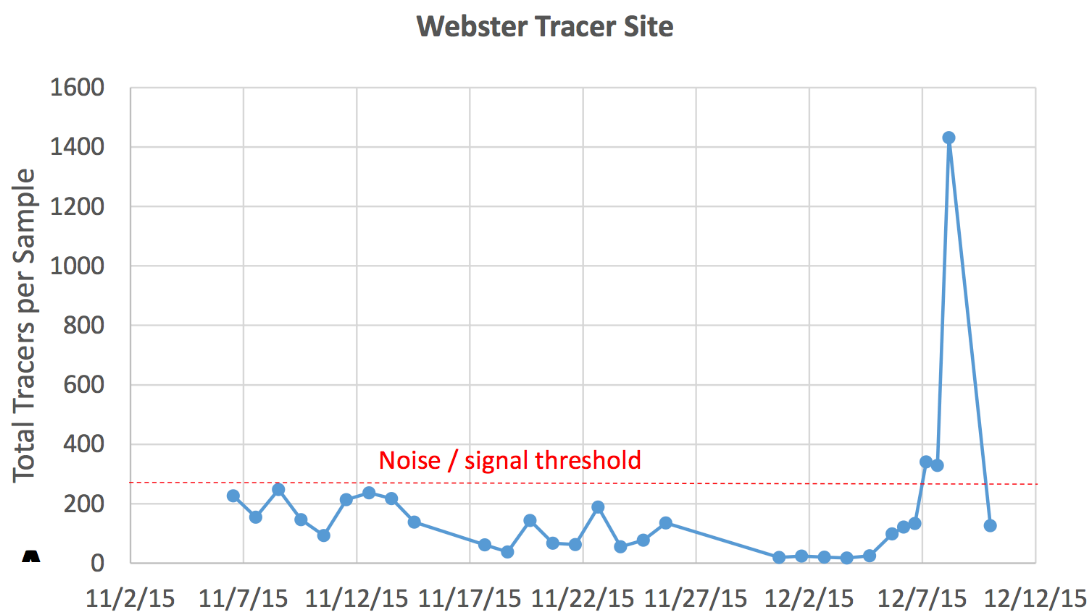


Figure 4: The y-axis of sample copies/min value ratio is intended to normalize any differences between sample runs. The star in a) indicates that the sample taken at 8.5 hours is off the scale of this graph, the true value is at 25.9 sample copies/min copies.

In experiment 2, T3 DNA tracer was introduced on November 6, 2015 at 1:13PM to the first floor bathroom of the Baldwin Residence. The 45 ml solution contained a total of 7.48E8 individual DNA tracer particles. Based on the shape of the plot of the number of DNA tracers detected (per sample), a break though curve occurred between 12/7/2015 and 12/8/2015 (**Figure 5**). Tracers numbering 250 per sample or below are considered instrument noise. Thus it took approximately 32 days for the tracer to move from the toilet, though the septic system, though the soil, through the stream and then to the sampler. This travel path includes movement through an instream pond, which will have increased the residence time of the stream water, as well as the dilution effects of groundwater recharge.



Conclusions:
The time each well received the tracer relates to distance from the leachfield as well as the preferential flow paths that may exist within the short-circuited leachfield. This tracer technology may be used to determine speed at which septic systems flush water and subsequently which may be contributing pollution to local water sources. The septic system tested likely has generated differential flow pathways, some draining significantly faster than others.

The presence of the tracer in the sample does not necessarily indicate fecal contamination. The presence of the tracer indicates hydrologic connectivity, and may be use to determine the rate at which septic leachate enters the water source. This data would then elucidate if the system is short circuiting and potentially contaminating the water source.

This technology has proved robust enough to be used in septic system testing, and is therefore an option when determining which septic system in a collection of several is the one contributing to pollution. It provides a relatively inexpensive means of acquiring septic data and simplifies previously used septic pollutant locator issues. Moving forward it would be helpful to understand the effect of the septic system on the tracer, if any. Additional research should be done to determine the lifespan of the DNA tracer in the environment, and possible ecological effects of these microplastics on the environmental system.

Acknowledgments:
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Innovative water treatment by chitosan modified diatomaceous earth for small public water systems in rural areas

Basic Information

Title:	Innovative water treatment by chitosan modified diatomaceous earth for small public water systems in rural areas
Project Number:	2016NY228B
Start Date:	3/1/2016
End Date:	8/31/2017
Funding Source:	104B
Congressional District:	NY-22
Research Category:	Water Quality
Focus Category:	Treatment, Water Supply, Toxic Substances
Descriptors:	None
Principal Investigators:	Xinchao Wei

Publications

1. Xinchao Wei, Nathaniel Cady, Aaron Mosier "Synergistic effect of metal combinations in ferrite nanoparticles for As (III&V) removal," The 252th ACS National Meeting & Expo, Aug. 21-25, 2016, Philadelphia, PA
2. Xinchao Wei, Carolyn Rodak, Robyn Christoferson, Stephen Nguyen "Contaminants removal by chitosan modified diatomaceous earth for small public water systems", Accepted by The 2017 AEESP Research and Education Conference, June 20-22, 2017, Ana Arbor, MI

Innovative water treatment by chitosan modified diatomaceous earth (DE) for small public water systems in rural areas

Progress Report

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Work Completed

1. Surface modification of diatomaceous earth (DE) by chitosan biopolymer to obtain a novel adsorbent with enhanced adsorptive properties.
    - The selected DE with different particle size and permeability was modified in the lab by chitosan under various conditions and pretreatments.
    - Different methods were tested to coat the chitosan onto the surfaces of DE, including: a) sudden pH adjustment of chitosan and DE mixture, b) slow pH adjustment of chitosan solution and DE mixture, c) pH adjustment of methanol treated chitosan and DE mixture, and d) pH adjustment of cross-linked chitosan and DE.

2. Evaluation of the adsorption performances of chitosan modified DE in removing organic matters, nitrate and arsenic.
    - Batch adsorption experiments were performed in the laboratory using the new adsorbents prepared using different methods.
    - The performance of modified ED in removing humic acid (Sigma-Aldrich), a surrogate for natural organic matters (NOM), was examined in the lab.
    - The performance of modified DE in removing nitrated was investigated.
    - The performance of modified De in removing arsenic was estimated using Hatch test kits because of the breakdown of analytic equipment (GFAAS).

Preliminary Conclusions

- Chitosan modified DE using different coating methods performed differently in removing contaminants of interest.
- Slow pH adjustment of chitosan and DE mixture resulted in adsorbents with better adsorption performance.
- All chitosan modified DE showed effective removal of natural organic matters (NOM), a precursor of disinfection byproduct.
- The performances of all chitosan modified DE in removing nitrate were not significant.
- The preliminary results indicated chitosan modified DE had great potential in removing arsenic.

Presentations

- Xinchao Wei, Carolyn Rodak, Robyn Christoferson, Stephen Nguyen "Contaminants removal by chitosan modified diatomaceous earth for small public water systems", Accepted by *The 2017 AEESP Research and Education Conference,* June 20-22, 2017, Ana Arbor, MI
- Xinchao Wei, Nathaniel Cady, Aaron Mosier "Synergistic effect of metal combinations in ferrite nanoparticles for As (III&V) removal," *The 252th ACS National Meeting & Expo*, Aug. 21-25, 2016, Philadelphia, PA

Student Supported

- Robyn Christoferson
- Stephen Nguyen
- Alex Eanniello

Student Researcher Support of Adaptive Management of the St Lawrence River using Novel Water Quality Monitoring Methodology

Basic Information

Title:	Student Researcher Support of Adaptive Management of the St Lawrence River using Novel Water Quality Monitoring Methodology
Project Number:	2016NY229B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	NY-23
Research Category:	Water Quality
Focus Category:	Surface Water, Water Quality, Methods
Descriptors:	None
Principal Investigators:	Michael Twiss, Joseph Skufca

Publications

1. Twiss, M. R., Russo, A. M., Neff, F. C., Skufca, J. D., 23rd Annual River Symposium, St. Lawrence River Institute of Environmental Sciences, Cornwall, Ontario, "Water Quality Monitoring in the St. Lawrence River Using a Novel Approach of Sensors Located Inside of Hydroelectric Power Dams: 2014 to 2016", (May 2016)
2. Evie Brahmstedt, Erin Eggleston, Thomas Holsen, Hao Zhou, Joseph Joseph. Skufca, Michael Twiss. Potential for Water Level Regulation in the St. Lawrence River to Affect Sustainable Fish Populations in the Face of Mercury Bioaccumulation. St. Lawrence University Festival of Science, April 2017
3. TWISS, M.R., SKUFCA, J.D., SHIRKHANI, H., RUSSO, A.M., LUMBRAZO, C., NEFF, F.C., SPRAGUE, H., LOFTUS, S.E. and RIDAL, J.J. Novel sensor deployments in a hydropower dam on the Saint Lawrence River. 60th International Association for Great Lakes Research Annual Conference, May 18, 2017, Detroit, Michigan; http://iaglr.org/iaglr2017/)

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Student Researcher Support of Adaptive Management of the St Lawrence River using Novel Water Quality Monitoring Methodology

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Senior Personnel: Michael T. Dagrossa, BA, Clarkson University, Potsdam, NY, 13676, tel: (315)-268-6741; email: mdagross@clarkson.edu

Abstract: Restrictive water level regulation in the Saint Lawrence River over the past 50 years has had a profound impact on ecosystem health. Currently, there are no explicit plans to determine how the restoration of more natural water level regimes in the St. Lawrence will impact water quality, although great effort has been made to develop adaptive management as the proper strategic approach. Water quality sensor arrays will be continuously operated in the Moses-Saunders hydropower dam to provide data that can relate change in water quality to changes in water levels. Mercury will be measured in water flowing through sensor arrays as well as in wetlands upstream that have the potential to release Hg with changing water level scenarios. The objective is to collect water quality data and relate this to water levels, to assess the potential for changing water levels to release Hg into the river and to produce three audience-appropriate videos to describe this important endeavor.

Above: *Summer intern Evie Brahmstedt of St. Lawrence University sampled St. Lawrence River wetlands for mercury content during the summer of 2016. Ms. Brahmstedt will present her research findings at the July 2017 International Conference on Mercury as a Global Contaminant in Providence, Rhode Island, and begin her doctoral studies in environmental science & engineering at Clarkson University in June, 2017 (Photo: M. Twiss, Clarkson).*

Three Summary Points of Interest

- **Point 1:** High resolution water quality data has been collected with the support of **students trained** on this project.
- **Point 2:** A preliminary assessment of legacy Hg contamination of St. Lawrence wetlands has been conducted and used to support receipt of two additional **awards** to expand this research.
- **Point 3:** One informative **video** has been produced and two additional videos geared to a technical and K-12 audience are in development.

Keywords: Great Lakes Water Quality Agreement (GLWQA), Area of Concern (AOC), mercury (Hg), St. Lawrence River, Great Lakes, education, training, Adaptive Management

Policy implication statement; products of interest and/or upcoming events:

Policy implication statement:
Water levels on the St. Lawrence River and Lake Ontario are proposed to be regulated by Plan 2014. Expected erosion of wetlands to a more naturally diverse structure that existed before the river was dammed may release mercury and nutrients trapped in the wetlands that have become entrenched over the past 60 years. The impact of this elemental mobilization on water quality will be observed and used to support adaptive management.

Products to date:

1. **Informative (lay audience) video:** How Do Saint Lawrence River Levels Affect Wildlife? https://www.youtube.com/watch?v=pspA7NZNdLc

Products of interest: Student Presentations Awards at the Summer 2016 SURE Conference, at Clarkson University (July 2016):

1. Best oral Presentation: *Environmental Sciences 2: Ecosystems*

   Brahmstedt, E., Holsen, T., Skufca, J., and Twiss, M.R. *"Potential for Water Level Regulation in the St. Lawrence River to Affect Sustainable Fish Populations in the Face of Mercury Bioaccumulation"*

2. Best oral Presentation: *Applied Mathematics & Data Processing*

   Lumbrazo, C., Skufca, J., and Twiss, M.R. *"Automated Data Cleaning for Exploratory Data Analysis of Water Quality in the St. Lawrence River"*.

Conference Presentations:

1. Twiss, M. R., Russo, A. M., Neff, F. C., Skufca, J. D., 23rd Annual River Symposium, St. Lawrence River Institute of Environmental Sciences, Cornwall, Ontario, "Water Quality Monitoring in the St. Lawrence River Using a Novel Approach of Sensors Located Inside of Hydroelectric Power Dams: 2014 to 2016", (May 2016).
2. Evie Brahmstedt, Erin Eggleston, Thomas Holsen, Hao Zhou, Joseph Joseph. Skufca, Michael Twiss. Potential for Water Level Regulation in the St. Lawrence River to Affect Sustainable Fish Populations in the Face of Mercury Bioaccumulation. St. Lawrence University Festival of Science, April 2017.
3. TWISS, M.R., SKUFCA, J.D., SHIRKHANI, H., RUSSO, A.M., LUMBRAZO, C., NEFF, F.C., SPRAGUE, H., LOFTUS, S.E. and RIDAL, J.J. *Novel sensor deployments in a hydropower dam on the Saint Lawrence River.* 60th International Association for Great Lakes Research Annual Conference, May 18, 2017, Detroit, Michigan; http://iaglr.org/iaglr2017/)

Future conference presentations

1. Evie Brahmstedt, Erin M. Eggleston, Hao Zhou, Thomas M. Holsen, and Michael R. Twiss. Mercury mobilization in response to changing water level management plans designed to restore wetland biodiversity in the Upper St. Lawrence River. 13th International Conference on Mercury as a Global Pollutant (ICMGP 2017) Conference in Rhode Island, July 16-21, 2017.
2. Evie Brahmstedt, Erin M. Eggleston, Hao Zhou, Thomas M. Holsen, Joseph D. Skufca, Jeffrey J. Ridal, and Michael R. Twiss. Plan 2014 in the St. Lawrence River may impact mercury bioaccumulation in the aquatic food web. 24th River Symposium, Cornwall, ON (May 31, 2017).
3. Michael R. Twiss, Hamidreza Shirkhani, Joseph D. Skufca, Anthony M. Russo, Cassie Lumbrazo, Neff, Faith C., Heather Sprague, Sarah, E. Loftus, and Jeffrey J.Ridal; Novel sensor deployments in a hydropower dam on the Saint Lawrence River 24th River Symposium, Cornwall, ON (May 31, 2017).

Title Student Researcher Support of Adaptive Management of the St Lawrence River using Novel Water Quality Monitoring Methodology

Student training

Name	Program (University)	Project	Date
Anthony Russo	Environmental Science and Engineering; graduate (Clarkson)	The REASON Network: Water quality Sensing in a Power Dam	Sept 2014--May 2016
Evie Brahmstedt	Environmental Studies (St. Lawrence Univ.)	Mercury content in St. Lawrence River wetlands	Summer 2016 May-Aug
Colby DeVane	Chemistry and Social Entrepreneurship (Erskine College)	Sensor calibration for river sensor network	Summer 2016 May-Aug
Cassie Lubrazzo	Mathematics & Environmental Engineering (Clarkson)	Methods for cleaning data sets from sensor network	Summer 2016 May-Aug
Ian Vitek	Biology (Clarkson)	Sensor array maintenance	Jan. –April 2017

Additional funding received related to this proposal:

1. ***Source-Tracking Mercury (Hg) Mobilization from the St. Lawrence River Wetlands***; Best-in-Science program, Ontario Ministry of the Environment and Climate Change - subcontract from the St. Lawrence River Institute of Environmental Science: $CAD 62,050.
2. ***Studies on mercury mobilization from wetlands along the Upper Saint Lawrence River in support of Ecosystem-Based Management;*** Great Lakes Research Consortium Small Grants program was selected to be funded in the amount of $20,338.

Summary of progress to date:

To date we have trained one graduate student (masters) and four undergraduate students. One additional undergraduate student (Cindy Rodas, Salisbury College) will begin training May 22. Evie Brahmstedt will begin her doctoral research on this topic June 1.

We have collected water quality data continuously at the Moses-Saunders hydropower dam and have expanded our network to the Canadian side of the power dam, with colleagues at the River Institute in Cornwall, Ontario, and to the mid-channel (NY). Data were presented at the IAGLR meeting in Detroit (May 2107).

One informative video (available on YouTube, *see above*) has been prepared and two additional educations videos will be produced in by August 2018.

A manuscript describing the use of the power dam to monitor water quality (365 days per year) is underway.

***

This report was prepared for the New York State Water Resources Institute (WRI) and was made possible through funding authorized under Section 104b of the Water Resources Research Act, administered by the US Geological Survey

Conductivity and nutrient monitoring in surface water's of NY's Finger Lakes region

Basic Information

Title:	Conductivity and nutrient monitoring in surface water's of NY's Finger Lakes region
Project Number:	2016NY231B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	NY-23
Research Category:	Water Quality
Focus Category:	Water Quality, Surface Water, Solute Transport
Descriptors:	None
Principal Investigators:	Todd Walter

Publications

1. Morse, N., McPhillips, L., Shapleigh, J., Walter, M.T. (2017 In Review). The role of denitrification in stormwater detention basin treatment of nitrogen. Environmental Science and Technology
2. Lisboa, MS.; Schneider, R., Walter, MT. Landuse and drought effect on P loads at the Owasco Lake watershed, NY. AGU 2016

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Nutrient monitoring in surface water's of NY's Finger Lakes region

Dr Brian G Rahm; M Sol Lisboa; Natalie Morse; Chelsea Morris & Dr Todd Walter
Biological & Environmental Engineering, Cornell University

Abstract

Surface waters in upstate New York are often subject to contamination by nutrients as a result of point and non-point source discharges. While these impairments are notionally related to land use and resource management, the driving force behind these relationships is often unknown. In the Finger Lakes region, there are a range of streams and lakes within watersheds characterized by varying degrees of urbanization, and subject to various agricultural activities and municipal inputs (eg. wastewater treatment effluent). The aim of this project was to help develop regionally-based hypotheses for stream and lake impairments by collecting data from suspected contamination sources. Funding was also used to train students in field and lab methodologies, and generate a broader appreciation for issues related to land use, hydrology, and management in the Finger Lakes region.

Three Summary Points of Interest

- **In the Owasco Lake watershed, we observed higher fall phosphorus loading from agricultural areas compared to forested areas**
- **In winter, we observed the effects of manure spreading on frozen ground in an agriculturally-dominated watershed**
- **In stormwater infiltration basins, drainage rates can be a driving factor of nutrient transformation**

Keywords: Phosphorus, Nitrogen, Nutrients, Owasco Lake, Finger Lakes, Stormwater

Title

Introduction

In New York, surface waters are subject to excess nutrient loadings, in large part due to transport from land surfaces during storm events. Concentrations of nutrients (phosphorus and nitrogen) have been increasing in surface waters as a result of point source contamination (eg. from wastewater treatment facilities) and non-point source contamination (eg. agricultural activities). In the Finger Lakes region of upstate NY, there are a variety of surface waters with quality that ranges from nearly pristine to impaired, as well as watersheds that range from urban to agricultural. A regional effort is needed to monitor these surface waters to better understand how land use and regional infrastructure may be leading to nutrient impairment.

Results & Discussion

<u>A focus on Owasco Lake</u>

Owasco Lake, located in Central NY, supports agriculture and industrial activities, and constitutes the main drinking water source for its community. The lake and its watershed are exposed to a variety of environmental threats, with non-point source pollution being one of the major concerns. Phytoplankton growth in the lake is phosphorus (P) limited and lake P concentrations have been on the rise for several years (CEE, 2004; Halfman & Bush 2006; Halfman et. al. 2014, 2015 and 2016). In order to establish effective P control strategies for the Owasco Lake watershed, we have begun to identify and quantify diffuse sources of phosphorus, specifically from agricultural lands adjacent to the lake and its tributaries.

In 2016, we conducted monitoring of 12 tributaries (Figure 1) to the lake during base and storm-flow conditions. We analyzed samples bi-weekly for Total Phosphorus (TP), Soluble Reactive Phosphorus (SRP), Nitrate and Total Suspended Solids (TSS). We observed a consistent pattern of higher TP and SRP loads for agricultural sites (TP annual mean: 1.42±4.26 mg/s km^2, SRP annual mean: 1.11±1.08 mg/s km^2) in comparison to forested areas (TP annual mean: 0.34±0.46 mg/s km^2, SRP annual mean: 0.26±0.25 mg/s km^2) when averaging results for all four seasons, although statistical analysis showed no significant differences between land-uses with this approach. Data analysis by season, however, did result in significant differences among land-uses during the fall, showing higher loads from agricultural areas than from forested areas (p-value=0.024 and 0.0002 for TP and SRP loads, respectively).

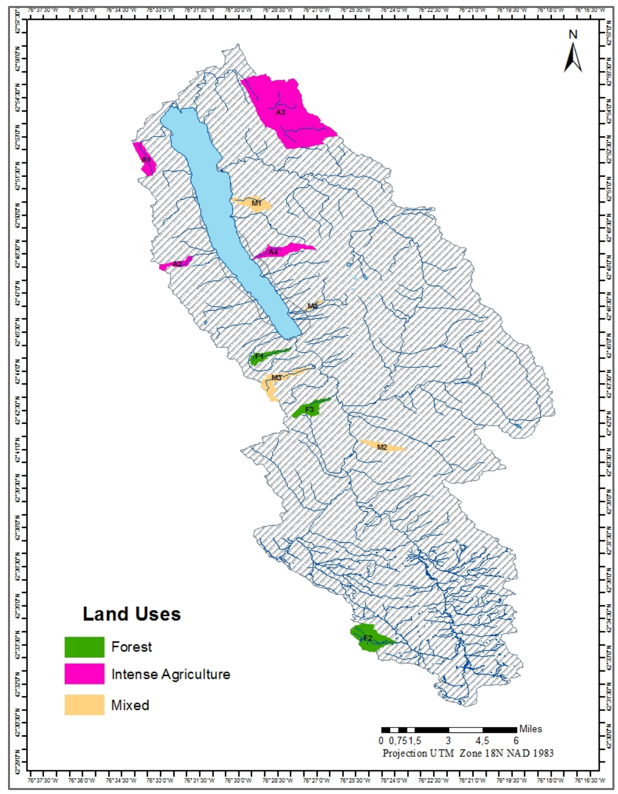

Figure 1: Owasco watershed sampling sites and land-use classification.

<u>Examining events associated with acute water quality impacts:</u> Elevated phosphorus detected in Salmon Creek following manure spreading event

Manure application to agricultural fields is common in NY and is often applied in excess of plant growth nutrient demands. Excess phosphorus (P) on cropland runs off into surface waters causing eutrophication and harmful algal blooms. The risk of P runoff increases when manure is applied to frozen ground (Komiskey et al., 2011). Rain falling on frozen ground is less likely to infiltrate and more likely to carry the fresh manure to surface waters.

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Title

In late winter of 2017, we observed the effects of manure spread on frozen ground in an agriculturally-dominated watershed. Daily water quality grab samples were analyzed for soluble reactive phosphorus, total phosphorus, and sediment.

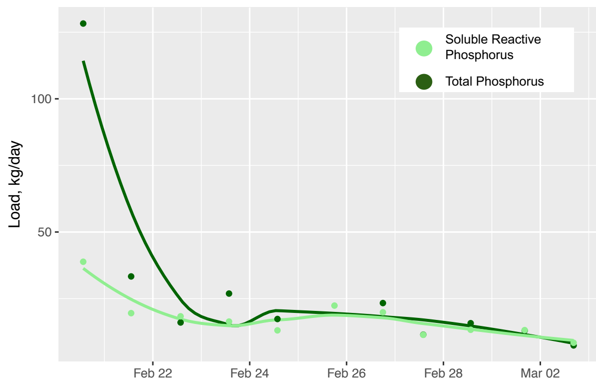

Figure 2. Elevated total phosphorus loads were observed two days after a large rain event and three days after manure spreading on frozen soil (Figure). High sediment (data not shown) and low soluble reactive phosphorus concentrations over the first two days suggest the presence of fresh manure in the stream.

We are continuing to monitor nutrient transport during storm events in agricultural watersheds.

<u>Assessing stormwater BMPs for multiple benefits</u>

The nitrogen (N) cycling dynamics of four stormwater basins, two often saturated sites ("Wet Basins") and two quick draining sites ("Dry Basins") (Figure 3), were monitored over a ~1-year period. This study paired environmental monitoring (stormwater and greenhouse gas) and microbial analyses to elucidate the mechanisms controlling N treatment.

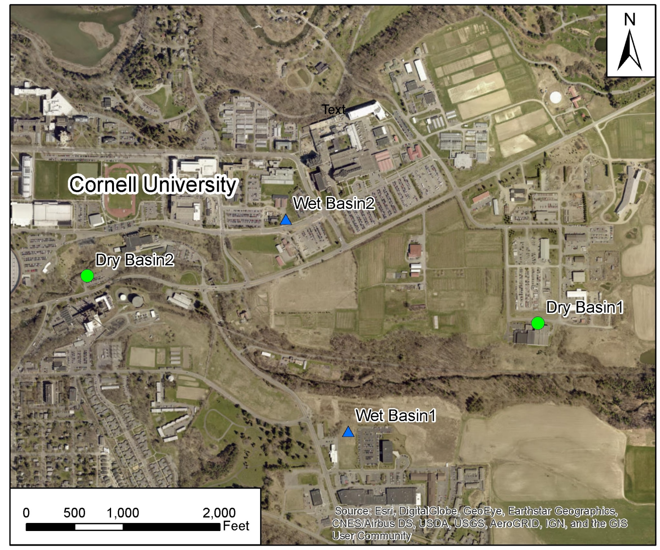

Figure 3. Stormwater site layout

Annual dissolved inorganic N (DIN) mass reductions (inflow – outflow) were greater in the Dry Basin than in the Wet Basin, 174 vs. 135 mg N m^{-2} yr^{-1}, respectively. Incoming and outgoing DIN concentrations were statistically the same for both sites. The Dry Basin infiltrated a much larger volume of water and thus had greater DIN treatment (inflow – outflow) due to volume reductions. However, Wet Basins had higher proportions of denitrification genes and potential denitrification rates. These results emphasize the need for more mechanistic attention to basin design because the reductions calculated by comparing inflow and outflow loads may not be relevant at watershed scales. Denitrification is the only way to fully remove DIN from the terrestrial environment and receiving waterbodies. The Wet Basin denitrified about 40% of incoming DIN, while the Dry Basin only denitrified 6%. Consequently, at the watershed scale the Wet Basin may have produced better overall DIN treatment.

Methods

For Owasco Lake watershed and Salmon Creek sampling:

Grab water samples were collected for TP, SRP, Nitrate and Sediments analysis during 2016, with a monthly frequency in winter and biweekly over the rest of the year. Orthophosphate concentration was determined by the Mb-blue method (USEPA 1978) on an automated wet-chemistry analyzer (FS3000; Xylem Analytics O.I.

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Analytical, Beverly, Massachusetts). TP samples were previously digested with persulfate and sulfuric acid (Method 4500-P B5, APHA 1998); and filtered through a 0.45 µm filter (Supor Membrane Disc Filter, 25-mm diameter; Pall Life Sciences, Port 173 Washington, New York). Water samples for TSS analysis were filtered using a 0.47 µm filter and then the filter was dried in a 60ºC oven for 24 hrs. TSS concentration was determined by calculating the mass difference of the filter before and after oven dried, divided by the water volume filtered. Nitrate was determined using the sulfanilamide colorometric method based on Doane and Horwath (2003) on a microplate reader. Nutrient loads were calculated as the product of discharge and nutrient concentration.

For stormwater sampling:
ISCO automated samplers (ISCO 6712) collected stormwater samples over the storm duration. To capture the general water quality, the individual samples were flow-weight composited for an event mean concentration (EMC), prior to analysis. Consequently, one inflow and one outflow sample characterized each storm at each site. Stormwater samples were analyzed for NO_3^- and NH_4^+ colorimetrically in 2015 via Lachat QuikChem 8000 Flow Injection Analyzer and in 2016 via microplate reader.

Productss/Outreach

Morse, N., McPhillips, L., Shapleigh, J., Walter, M.T. (2017 In Review). The role of denitrification in stormwater detention basin treatment of nitrogen. Environmental Science and Technology.

Lisboa, MS.; Schneider, R., Walter, MT. Landuse and drought effect on P loads at the Owasco Lake watershed, NY. AGU 2016, poster presentation.

Talk at Owasco Lake Association (OWLA) meeting on March 1, 2017. Nutrients Loads to the Owasco Lake from small tributaries: 2016 monitoring results. Lisboa MS, and Walter, MT.

Talk at Dairy One, Ithaca NY, on April 23 2017. Nutrients Loads to the Owasco Lake from small tributaries: 2016 monitoring results. Lisboa and MS, Walter, MT.

Student Training

Two undergraduates assisted with the stormwater monitoring in Ithaca, New York.

One undergraduate helped with Owasco tributaries monitoring between June and August 2016.

Additional final reports related to water resource research are available at
http://wri.cals.cornell.edu/news/research-reports

References

Komiskey, M. J., et al. "Nutrients and sediment in frozen-ground runoff from no-till fields receiving liquid-dairy and solid-beef manures." *Journal of Soil and Water Conservation* 66.5 (2011): 303-312.

Cornell Cooperative Extension (CEE), 2004. Total Phosphorus Sampling Program for the Cayuga and Owasco Lake Watershed.

Halfman, J.D., B.L. Holler, and H.M. Philip, 2006. A preliminary water quality study of Owasco Lake, NY, and its watershed. Finger Lakes Institute, Hobart and William Smith Colleges. 26 pg

Halfman, J.D., G. Moralez, K. Coughlin, and N. Andrzejczyk, 2014. Owasco Lake, New York: Water quality and Nutrient Sources, 2014 Findings. Finger Lakes Institute, Hobart and William Smith Colleges. 43 pg.

Halfman, J.D., K. Coughlin, A. Dylag, R Ratsep, & N. Tanquary. 2015. Owasco Lake, New York 2015 Annual Report: Water Quality & Nutrient Source Monitoring, Detailed Dutch Hollow Nutrient Loads & Detailed Water Quality Buoy Data. Finger Lakes Institute, Hobart and William Smith Colleges. 48 pg.

Halfman, J.D., H.A, Simbliaris, B.N. Swete, S. Bradt, M.C. Kowalski, P Spacher & I. Dumitriu. 2016. The 2016 Water Quality Report for Owasco Lake, NY. Finger Lakes Institute, Hobart and William Smith Colleges. 51 pg.

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Information Transfer Program Introduction

The Director and staff of the NYS Water Resources Institute undertake public service, outreach, education and communication activities. Most are conducted through multidisciplinary projects funded outside the Water Resources Research Act (WRRA) context. In order to couple WRRA activities to other NYS WRI activities, a portion of WRRA resources are devoted to information transfer through a partnership program with the Hudson River Estuary Program, dissemination of information related to emerging issues, and student training.

Hudson River Estuary Program Partnership

Funded by the NYS Department of Environmental Conservation (DEC), the program is guided by 12 goals as part of its Action Plan formed in 1996. These goals address signature fisheries, river and shoreline habitats, plants and animals, streams and tributaries in the entire watershed, landscape and scenery, public access, education, waterfront revitalization, water quality, and partnerships and progress. WRI and DEC work together to protect this rich estuary ecosystem that is a source of municipal drinking water, spawning grounds for migratory fish, habitat for bald eagles, and an excellent recreation area for boaters, anglers and swimmers.

A summary of selected WRI information transfer activities is provided below

NYSWRI Publications

1. Water Resource Infrastructure in New York: Assessment, Management, & Planning – Year 4, Prepared November 11, 2016

Conference Presentations & Invited Talks

1. Rahm, B.G., S. Hwang, T. Joo, K. Teuffer, S. Vedachalam, D. Grantham, S.J. Riha, “Making the case for OWTS management: lessons from case studies and research,” AGU Fall Meeting, 2016, San Francisco, CA - poster

2. Kirsch, A., Mosier, E., Watkins, L., Rahm, B.G., Roessler, B., Walter, M.T.; “Monitoring riparian restoration: Trees for Tribs in the Hudson and beyond” Annual Watershed Conference, Hudson River Watershed Alliance, 2016, Hyde Park, NY – poster

3. “Managing OWTS: Lessons from case studies and research” Training provided for the NY Rural Water Association Onsite Wastewater Treatment Management session, Maybrook, NY, June 9, 2016 - Invited talk - 45 attendees

4. Rahm, B.G.; “Managing OWTS: Lessons from case studies and research” Fifth Northeast Onsite Wastewater Treatment Short Course and Equipment Exhibition, New England Interstate Water Pollution Control Commission, 2016, Taunton, MA – talk

Public Comments

1. Comments on the Preliminary International Joint Commission Recommendations on Microplastics in the Great Lakes, submitted by Lisa Watkins, Brian G Rahm and M Todd Walter to the International Joint Commission, November, 2016

Service

1. Participant in 2016 Town-Gown Resource Fair, Ithaca, NY

2. Workshop co-planner & moderator: Green Infrastructure Research to Guide Implementation and Policy, 2016, Albany, NY

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	12	0	0	0	12
Masters	2	0	0	0	2
Ph.D.	1	0	0	0	1
Post-Doc.	1	0	0	0	1
Total	16	0	0	0	16

Notable Awards and Achievements